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Grain morphology of heavy minerals from marine and continental placer deposits, with special reference to Fe–Ti oxides

H.G. Dill

Federal Institute for Geosciences and Natural Resources, P.O. Box 510163, D-30631 Hannover, Germany

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Abstract

The grain morphology of major heavy minerals from various placer-type mineral deposits (aeolian, beach, fluvial, alluvial, colluvial, residual–eluvial) in Mongolia, USA, Vietnam, Latvia, Germany, Spain, Cyprus, South Africa and Nepal was studied by means of SEM, conventional petrographic microscopy and visual inspection. Variation of grain morphology is first and foremost controlled by the physical and chemical processes operative in the environment of deposition and to a lesser extent by the climatic conditions. The sphericity of grains in the mineral assemblage strongly depends on the crystallographic system of the prevailing heavy minerals. It improves as minerals such as spinel and garnet, the most common representatives of the cubic crystallographic system, become more and more prominent among the heavy minerals in the placer material. Even if minerals belong to the same crystallographic system there may be significant differences as to their roundness. Analysis of the grain morphology of garnet shows an increase in angularity from the pyrope – through almandine-, grossularite- to the spessartite-enriched garnet solid solution series in the placers under consideration. Spessartite-enriched garnet solid solution series are widespread in pegmatites and low-grade metamorphic rocks where they normally form euhedral crystals. Such morphological differences in a solid solution series are inherited from the source rock and are not modified by sedimentary processes in proximal placer deposits. Thus isometric minerals such as spinel or garnet are not good marker minerals for depositional environments. Their strong points lie in the field of provenance rather than environment analysis as far as grain morphology is concerned. For a refinement of the morphology-based subdivision of depositional environments, particular groups of minerals have to be selected for the various types of placer deposits. There is no universal mineral ubiquitous to all placers whose morphological changes and surface textures are a direct indicator of a particular environment of deposition. Redox-sensitive minerals such as Fe–Ti compounds taking an intermediate position on the Mohs's hardness scale and being fairly resistant to weathering have proven to be a good tool for the distal placer types, spanning the full range from beach to fluvial placers, and including aeolian types. Ultrastable to stable mineral such as corundum *sensu lato*, kyanite or zircon are more appropriate for a morphology-based environmental analysis in proximal types, covering the full spectrum from fluvial to residual–eluvial and colluvial placer deposits.

Keywords: Placer types; Continental; Marine; Grain morphology; Climate; Environment of deposition

1. Introduction

The chemical composition of mineral grains, their intergrowth with other minerals of similar size or with accessory minerals included in heavy mineral aggregates, may successfully be used to characterize heavy mineral assemblages with respect to provenance and supergene alteration (Morton, 1991; Dill, 1998; Morton and Hallsworth, 1999; Dill et al., 2006, in press). Shape, surface textures and the size of minerals in clastic

E-mail address: dill@bgr.de.

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sediments are often as important as the chemical composition of the mineral, itself. The typology of minerals like zircon has successfully been used to draw a more precise picture of the source rock in which they have evolved (Pupin and Turco, 1981; Schäfer and Dörr, 1997). The roundness of apatite has been shown to be a useful environmental indicator by Allen and Mange-Rajetzky (1992) and Morton et al. (2003). The shape and surface characteristics of platinum-group elements, gold, and quartz grains examined with the scanning electron microscope show transit- and transport-related changes (Nikolayeva and Yablokova, 1989; Southam and Beveridge, 1994) and the outward appearance of particles of precious metals may also provide some valuable evidence for exploration geologists and guide them to the primary deposit of placer-type minerals (Herail et al., 1989; Eyles, 1995; De Oliveira and De Oliveira, 2000; Duk-Rodkin et al., 2001; Nakagawa et al., 2005). Scanning electron microscopy (SEM) can best broaden our knowledge of the morphological and compositional variations of heavy minerals, supplementing conventional petrographic microscopy and visual inspection under the stereomicroscope during heavy mineral analysis. This technique has proven to be the most efficient tool for studying grain-surface textures in a wide range of minerals (Henning and Störr, 1986; Marshall, 1987; Trewin, 1988; Tucker, 2001). Scanning electron micrographs of heavy minerals from different types of placer deposits in continental and marine environments are discussed in this paper (Fig. 1). The impacts of the depositional environment, transport and climate on the morphology of heavy minerals are the focus of discussion during the present study of grain morphology. It goes without saying that morphology and texture as well as the intergrowths among heavy minerals are also of utmost importance for the industrial use of placer minerals. In particular, Fe–Ti compounds such as ilmenite and Ti-bearing magnetite rank very high among placer minerals of commercial interest. Mineralogical association and textural relationships, such as exsolution lamellae, grain size, intergrowth of minerals and the quantity of certain trace elements, e.g., Cr, V and Nb, are decisive for the final industrial use of Ti minerals. They find application in a wide range of branches and have thus been intensively studied *inter alia* by Flinter (1959), Wort and Jones

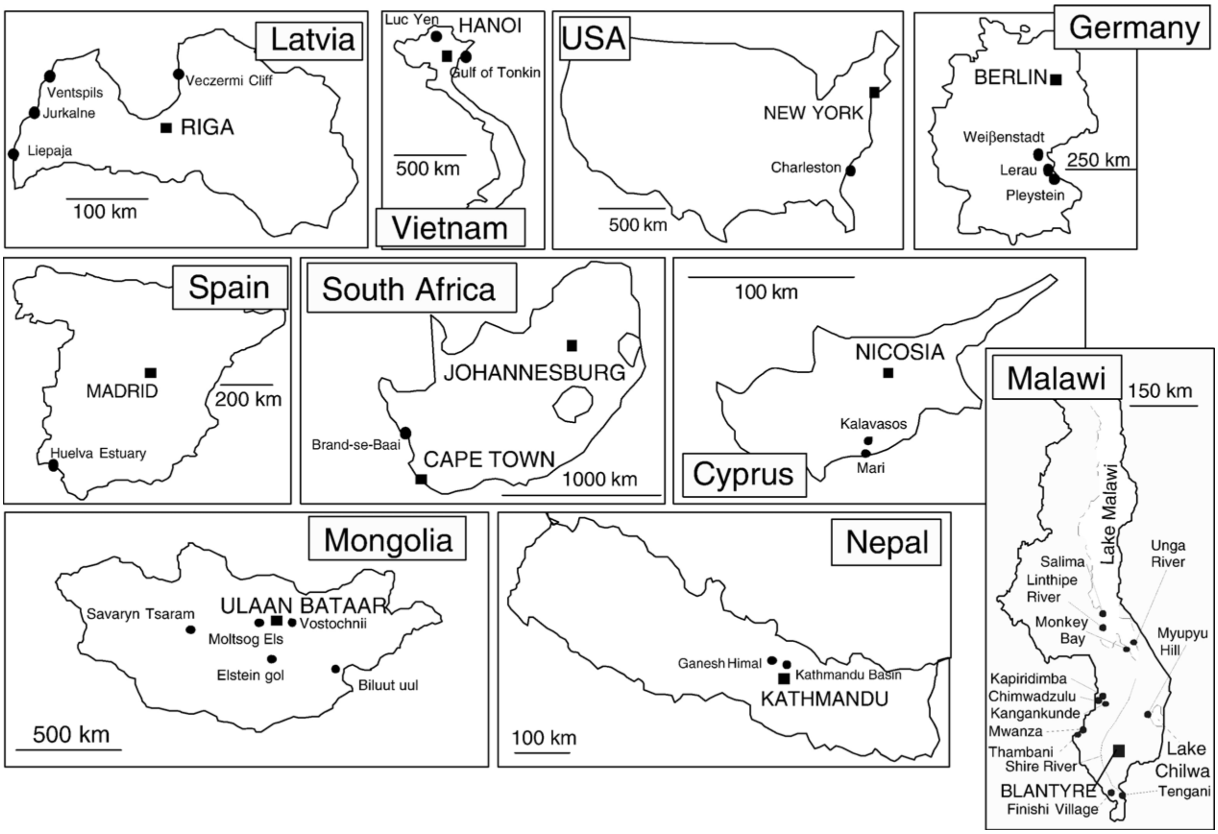

Fig. 1. Index map to show the position of placer deposits (full dots) referred to in this text and some major towns (full square).